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Test and Evaluation Report

USS MERRIMACK (AO 179) Jumbo Post-Jumboization Standardization Trials

by

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The USS MERRIMACK (AO 179) Jumbo is the first CIMARRON Class oiler to be jumboized. A 108-ft (32.92-m) parallel middle body was added to the ship, increasing full load displacement from 27,400 long tons (27,800 t) to 36,890 long tons (37,480 t). A five-bladed propeller was installed replacing the original highly skewed seven-bladed propeller, and the rudder was enlarged.

Standardization Trials were conducted on the jumboized USS MERRIMACK during the period of 11 to 14 July 1991. These trials were conducted at the Hatteras East Coast Tracking Offshore Range (HECTOR). This report presents the trial results.

At heavy displacement, the maximum ship speed attained was 21.95 kn. This was accomplished with an average shaft speed of 101.3 r/min, a total shaft torque of 1,241,500 lb-ft (1,682,500 N-m), and a total shaft

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USS MERRIMACK (AO 179) Jumbo

ABSTRACT

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ADMINISTRATIVE INFORMATION

The work described herein was performed by the Carderock Division, Naval Surface Warfare Center (CARDEROCKDIV, NSWC), Code 1523 located at the David Taylor Model Basin (DTMB). This project was carried out under work unit 1523-587. The funding source was the Naval Sea Systems Command (NAVSEA), PMS 383.

INTRODUCTION

The USS MERRIMACK (AO 179) Jumbo is the first CIMARRON Class oiler to be jumboized. A 108-ft (32.92-m) parallel middle body was added to the original ship, increasing design full load displacement from 27,400 long tons (27,800 t) to 36,890 long tons (37,480 t). A five-bladed propeller was installed replacing the original highly skewed seven-bladed propeller.

The rudder was also enlarged to a profile area of 408.5 ft^2 (38.0 m^2). MERRIMACK is powered by a General Electric steam turbine generating a total design power of 24,000 shp (17,930 kW).

The reduction gear was manufactured by General Electric and Combustion Engineering provided the boilers. Principal ship and propeller characteristics are shown in Table 1.

The Standardization Trials are part of the Naval Sea Systems Command (NAVSEA) Performance and Special Trials which are generally conducted on the lead ship of a class. Other trials which come under this program are Tactical and Maneuvering Trials, Vibrations Trials, and Fuel Economy Trials.

This report presents the Standardization Trials conducted off the coast of North Carolina on the Hatteras East Coast Tracking Offshore Range (HECTOR) during the period of 11 to 14 July 1991. A detailed description of HECTOR can be found in Appendix A. Tactical and Maneuvering Trials were also conducted by representatives of the DTMB Full Scale Trials Branch during this time frame, and are reported in a document of higher classification.* The ship's force (crew) was enthusiastic and extremely helpful in nearly all aspects of the sea trials. Model correlation tests were performed at DTMB by the Design Evaluation Branch using data from this Standardization Trial for comparison (Forgach[1]).

HULL INSPECTION

Prior to launch, the ship's underwater hull and appendages were painted. The following paint was applied:

1. Bottom - 1 coat Formula 150 green epoxy polyamid primer (7 mil), 1 coat Formula 151 haze gray epoxy polyamid topcoat (3 mil), 1 coat Formula 154 gray epoxy polyamid topcoat R-36 (3 mil), and 2 coats Formula 121/63 red antifouling vinyl (5-6 mil).

2. Boot Topping - 1 coat Formula 150 green epoxy polyamid primer (7 mil), 1 coat Formula 151 haze gray epoxy polyamid topcoat (3 mil), 1 coat Formula 154 gray epoxy polyamid

* Johnson, Eric H., David Taylor Research Center, as reported in CDNSWC-92/005, a report of higher classification.

topcoat R-36 (3 mil), and 3 coats Formula 129/63 black antifouling vinyl (2 mil, 1 mil, 1 mil).

3. Rudders and Struts - 1 coat Formula 150 green epoxy polyamid primer (7 mil), 1 coat Formula 151 haze gray epoxy polyamid topcoat (3 mil), 1 coat Formula 154 gray epoxy polyamid topcoat R-36 (3 mil), and 2 coats Formula 121/63 red antifouling vinyl (5-6 mil).

A hull survey was conducted 22 to 23 May 1991 (49 days prior to the HECTOR trials) to determine whether the MERRIMACK's hull and appendages met the conditions specified in Chapter 081 of the NAVSEA Technical Manual "Waterborne Hull Cleaning of Surface Ships."[2] This manual details the condition of the hull and appendages necessary for conducting Navy Standardization Trials. The survey was conducted by a dive team from the Norfolk Ship Intermediate Maintenance Activity (SIMA) under the direction of a DTMB diving supervisor.

The survey indicated that the ship hull and appendage conditions satisfied the NAVSEA requirements for conducting Standardization Trials. Videotape and still photographs support this judgement. Divers also conducted a hull roughness survey (22 to 23 May 1991) using a British Ship Research Association (BSRA) surface roughness analyzer. Further details of this roughness survey can be found in Appendix B.

Upon completion of the hull documentation, the MERRIMACK was certified as having a hull paint condition which met all requirements necessary for conducting Navy Standardization Trials. The average hull roughness was found to be 195 μm (0.0077 in.).

TRIAL PROCEDURES

The Standardization Trials were conducted in accordance with Chapter 094 of the Naval Ship's Technical Manual.[3] Trial conditions and the displacements are listed in Table 2. Wind and sea conditions were generally considered good for conducting the full load displacement portion of the Standardization Trials, but the wind and sea state were approaching marginal conditions by the end of the light load portion of the trial.

Two or three passes were made over the tracking range at selected speeds. Prior to the start of each run, shaft speed was adjusted to the desired revolutions per minute according to the schedule listed in the trial agenda. After shaft torque and other powering parameters were steady, the run was started. During the run, rudder movement was restricted to ±2 degrees. Speed/powering curves were defined by comparing range speeds to ship powering conditions (r/min, torque, and shp) throughout the speed range for the various displacements and conditions tested.

The measurements taken during each run were: propeller shaft torque and r/min, Motorola Mini-Ranger Falcon positional data (used to calculate range speed), Electromagnetic (EM) log speed, ship's relative wind speed and direction (from both the DTMB installed anemometer and the ship's permanent anemometer), first stage shell pressure, ship's heading, and rudder position. Shaft horsepower was calculated from the measured shaft speed and torque. A data spot consisted of at least two passes over the range on reciprocal headings. If the difference in range speed for the two passes was less than 0.5 kn, the data for the two passes were simply averaged to yield a spot average. In the event that the speeds on reciprocal passes differed by more than 0.5 kn, a third pass was performed. In this case, a mean of means was used to arrive at an average for the data spot.

Stenson and Hundley[4] provide a more in-depth discussion of the general conduct of Performance and Special trials and measurement methods in DTRC report "Performance and Special Trials on U.S. Navy Surface Ships." These Standardization Trials and the associated Model Correlation Experiments (Forgach[1]) are also the subject of a detailed uncertainty analysis, which is reported separately.[*†]

INSTRUMENTATION AND MEASUREMENT UNCERTAINTIES

This brief discussion of the instrumentation and measurement uncertainties outlined in Table 3 will cover each signal as well as its source and calibration methods. It will also cover the calibration source, the resolution and accuracy of the measurement.

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* Forgach, Kenneth M., "Uncertainty Analysis of Model Correlation Experiment for USS MERRIMACK (AO 179) Jumbo," report in preparation, expected to be published in June 1992.

† Johnson, Eric H., "Uncertainty Analysis of Standardization Trials on a Navy Fleet Oiler," report in preparation, expected to be published in June 1992.

STEADY SHIP SPEED

Range Speed

Ship speed is calculated from ship position, which is obtained with a pulse-radar system. Prior to the trial, each component in the pulse-radar system is calibrated with all other system components by ranging a known distance. The pulse radar system has a resolution of 3 ft (0.91 m), a bias limit of 12 ft (3.66 m), and a precision limit of 15 ft (4.57 m).

Ship position data are collected for at least 3 min, with the ship speed for the run calculated by linear regression of position and time of successive data points. The steady state speed is equal to the slope of the resulting line. Further smoothing of the data is accomplished by differentiating time and distance from the first point to the mid point of the run, and discarding any points which fall outside two standard deviations of the point-to-point linear regression. The standard deviations commonly observed during Standardization Trials are 0.05 kn, which yields a precision limit of approximately 0.10 kn. The bias limit is estimated at 0.05 kn, based on range geometry and errors associated with the survey of the baseline.

EM Log Speed

The ship's installed EM log provides a measure of instantaneous speed. The measurement is taken from the ship's synchro circuit, and Standardization Trials can be used as a reference to calibrate this instrument. When calibrated, the EM log has an estimated bias limit of 0.25 kn, a precision limit of approximately 0.75 kn, and can resolve to the nearest 0.1 kn.

SHAFT TORQUE

Propeller shaft torque measurements were obtained with an Acurex 1645A strain-gauge bridge monitoring system. An hermetically sealed transducer mounted on a bending beam (sensor bar) generated a signal proportional to the propeller shaft twist. The bending beam was mounted between two rings which were clamped approximately 18 in. (460 mm) apart on the propeller shaft. A stationary electronics unit provided power to drive the rotating electronics and strain gauge bridge by electromagnetic induction. The output of the bridge was input to a rotating, low power transmitter. The transmitter signal was received by the stationary unit, demodulated, and conditioned, thereby generating an analog voltage proportional to torque. The Acurex torque system was calibrated by subjecting the sensor bar to precise displacement increments which were mathematically related to shaft torque using shaft characteristics and properties such as outside diameter, inside diameter, and modulus of rigidity. Torsionmeter characteristics are listed in Table 4. All of these characteristics affect the bias limit of the torque measurement, which is estimated at 2,080 lbf-ft (2,815 N-m). The precision limit associated with shaft torque is approximately 16,300 lbf-ft (22,057 N-m), and the smallest detectable change in torque is 200 lbf-ft (270 N-m).

SHAFT SPEED

Shaft speed (r/min) is measured by an infrared light sensor mounted adjacent to the shaft. A Mylar band with 60 evenly-spaced reflective strips, each separated by a nonreflective space was wrapped around the propulsion shaft. As the shaft rotated, a pulse was generated each time a reflective strip passed the sensor. The frequency of the pulses was directly proportional to shaft speed, and a frequency-to-voltage (F/V) converter changed the frequency signal to an analog voltage. The sensor and F/V are calibrated with an electronic oscillator. The bias limit is estimated at 0.38 r/min, and the precision limit is approximately 1.72 r/min. The shaft speed can be resolved to within 0.1 r/min.

FIRST STAGE SHELL PRESSURE

First stage shell pressure was obtained using a DTMB calibrated pressure transducer. The pressure transducer generated an analog voltage proportional to the pressure applied. The bias limit is approximately 0.5 psig (3.45 kPa) and the precision limit is estimated at 0.4 psig (2.76 kPa). The resolution of the pressure signal is 0.1 psig (0.69 kPa).

DRAFT AND DISPLACEMENT

Displacement was determined using visual readings in port, and the ship's Ballast Control System at sea. Visual draft readings can be determined to the nearest inch, and, for the range of displacements tested, the resolution of displacement readings was equal to 100 long tons (102 t). The bias associated with displacement is also 100 long tons (102 t). These bias estimates also apply to the displacements calculated by the ships ballast control system, as visual draft observations are the calibration source for the system. Draft readings and displacement calculations are discussed in greater detail in Appendix C and are tabulated in Table C.1.

SHIP'S RELATIVE WIND

Relative wind signals were recorded from a permanently mounted ship's anemometer on the superstructure and a DTMB-installed trial anemometer mounted as low and as far forward as possible. The DTMB wind anemometer provided more accurate data than the ship's anemometer, since (1) it is not affected by flow around the superstructure and masts like the ship's installed system, and (2) it is calibrated in a wind tunnel. Unfortunately, the DTMB anemometer failed shortly before the start of the light load standardization trials, forcing the use of the ship's installed system for these tests. The ship's relative wind data were recorded and generally compared favorably with the DTMB anemometer during the full load trials, so the wind data provided by the ship's anemometer is judged to be valid for the light load trials. The precision limits associated with both the permanent and trial anemometers are assumed to be identical, since the only difference in the equipment is its placement on the ship. Bias is more difficult to evaluate, especially in the case of the ship's anemometer, which could be affected differently by the changing air flow patterns around the superstructure. Both anemometers agreed within 1.6 kn and 6.1° during the full load Standardization Trials, so the bias errors are also assumed to be equal for each instrument. The estimated bias for wind speed is 0.1 kn with a precision limit of 1.1 kn, and a resolution of 0.1 kn. Wind direction has a bias limit of approximately 5.0°, due mostly to errors induced by visual alignment, with a precision limit of 3.3°.

RUDDER ANGLE

Rudder angle is measured from the ship's synchro circuit and is converted to an analog voltage with a synchro-to-analog converter. A calibration of the rudder quadrant in the steering gear room was performed before the start of the trial. The bias limit for the rudder angle is approximately 0.25°. The precision limit is estimated at 1.20° and the resolution of the rudder signal is 0.1°.

SHIP HEADING

Ship heading is obtained from the ship's gyrocompass. This is the only signal that DTMB does not calibrate. Because this instrument is vital to the safe navigation of the ship, DTMB relies upon the ship's force for accurate gyrocompass calibration. The bias limit associated with the heading is 0.25°, the precision is estimated at 1.40°, and the resolution is 0.1°.

DATA ACQUISITION EQUIPMENT

A Hewlett Packard (HP) R332 computer and a HP model 3852A Analog/Digital (A/D) measurement processor were used to digitize the analog signals. The resolution of the instrument was 15 bits at 30,000 mV, which means that the smallest detectable change in voltage for all signals was 0.915 mV. The effects of the A/D resolution are already included in the bias estimates of each signal. All the signals were digitized at a pre-determined rate and were utilized to determine the run averages as well as the maximum and minimum points. The data were recorded on an optical disk drive and displayed in a hard copy format from a HP model 9876A thermal printer. The data acquisition system is depicted in Fig. 1.

It is important to understand that the precision limit is a function of the standard deviation of the group of data being measured. As such, the precision limit reported here includes the unsteadiness of the process, and the ability to measure a signal accurately is only a part of the precision limit. Because many of the processes measured are inherently unsteady, the scatter observed in the data is at least partially a real phenomenon.

PRESENTATION AND DISCUSSION OF TRIAL RESULTS

Standardization Trial results are summarized in Tables 5 through 9 and are presented as curves in Figs. 2 through 9. The speed data are based on the International Nautical Mile, 6,076.1 ft (1,852.0 m). The data presented are for observed conditions and have not been corrected for wind effects or reduced to standard conditions of seawater temperature and density.

The design steady state engine parameters for the MERRIMACK and other ships of the USS CIMARRON (AO 177) Class are:

1. Design shaft torque -	1,260,480 ft-lbf	(1,708,177 N-m)
2. Design shaft speed -	100 r/min	
3. Design shaft power -	24,000 hp	(17,094 kW).

HEAVY VERSUS LIGHT DISPLACEMENT STANDARDIZATION TRIALS

Two Standardization Trials were conducted on the MERRIMACK at displacements of 33,600 long tons (34,100 t) and 29,000 long tons (29,500 t). The heavy displacement trial was conducted on 11 July 1991 and the light displacement trial was conducted on 13 and 14 July 1991. The results of these baseline Standardization Trials conducted at HECTOR are summarized in Tables 5 through 8. Speed/power data in whole number speed increments are developed from the data curves for model correlation comparisons, and are tabulated in Table 9. All the data are graphically depicted in Figs. 2 through 9.

The heavy displacement powering condition attained was:

1. Ship speed -	21.95 kn	
2. Average shaft speed -	101.3 r/min	
3. Total shaft torque -	1,241,500 lb-ft	(1,682,500 N-m)
4. Total shaft power -	23,940 hp	(17,860 kW)
5. Average first stage shell pressure -	451 psig	(3,107 kPa).

At this r/min of 101.3, the shaft torque reached 98% of maximum design torque and the shaft power was 99% of design.

When operating in a light displacement condition, the maximum performance observed was:

1. Ship speed -	22.25 kn	
2. Average shaft speed -	100.7 r/min	
3. Total shaft torque -	1,230,700 lbf-ft	(1,667,820 N-m)
4. Total shaft power -	23,610 hp	(17,613 kW)
5. Average first stage shell pressure -	442 psig	(3,046 kPa).

Both shaft power and torque were 98% of design.

Figures 2 and 3 clearly show that this ship exhibits an interesting relationship between the heavy and light displacement torque, horsepower, and shaft speed curves in that they cross at a point where the ship's speed corresponds to a speed-to-length ratio between 0.7 and 0.8. Normally, the heavy displacement curves are at or above the level of the light displacement curves until the ship's speed corresponds to a speed-to-length ratio between 0.8 and 1.0, where the heavy displacement curves diverge sharply upward. The heavy and light displacement curves crossed-over both in the model prediction tests and full-scale trials for the CIMARRON and the MERRIMACK. Model tests demonstrate that the bulbous bow increases total resistance at low speed, light load conditions, but as the ship's speed increases, the bow bulb reduces the overall resistance of the ship (VanMannen[5]). Consequently, the cross-over of the powering curves observed on full-scale trials can be attributed primarily to the effects of the bulbous bow. A "hump" in the low speed region and a "flatter" high speed region of the light displacement torque, horsepower and shaft speed curves in Figs. 2 and 3 are also results of this phenomenon.

COMPARISON OF STANDARDIZATION TRIALS FOR USS CIMARRON (AO 177) AND USS MERRIMACK (AO 179) JUMBO

The results of Standardization Trials on USS MERRIMACK (AO 179) Jumbo were compared to the results of similar trials conducted on USS CIMARRON (AO 177) as reported in September of 1982 (Koh[6]). The MERRIMACK was tested at a full load draft of 30.6 ft (9.32 m), 0.2 ft (0.06 m) trim by the stern and was compared to the CIMARRON which was tested at a full load draft of 31.1 ft (9.48 m) and 4.8 ft (1.46 m) trim by the stern. The additional length and volume of the jumboized ship precludes any meaningful comparisons at similar displacements. Consequently, normalizing the data from both sets of trials to similar speeds at nearly similar draft and trim conditions will provide useful comparisons. Direct speed comparisons of the two ships were calculated by developing standard speed tables for each ship from tabulated standardization data and comparing the powering parameters at those points. Table 9 is a sample of the type of table used for this analysis.

Figures 4 and 5 graphically show the comparison of the MERRIMACK and CIMARRON at full load displacement. Above 21 kn, the MERRIMACK requires 2% lower shaft speed, 3% less torque, and 5% less power than CIMARRON at the same speeds. Additionally, MERRIMACK attains a maximum speed of 21.95 kn, 0.4 kn faster than the top speed recorded for the CIMARRON. Below 21 kn, MERRIMACK requires 2% higher shaft speed, 6% more torque, and 9% higher horsepower than the CIMARRON for the same speed. These performance differences are expected for a lengthened ship with a lower speed-to-length ratio and greater wetted surface area. Despite the differences in trim for these tests, the drafts of the two ships as tested were within 2%. Therefore, this comparison is judged to be representative of the jumboized AO 177 Class ships.

Figures 6 and 7 depict the comparison of CIMARRON and MERRIMACK as tested in the light displacement condition. The MERRIMACK requires an average of 1% higher shaft speed, 4% more torque, and 5% higher horsepower for a given speed than the CIMARRON . Unlike the comparison of the ships at full load displacement, the MERRIMACK required consistently greater torque, shaft speed, and power than the CIMARRON at the light load condition, with no "cross-over." The different behavior of the light displacement powering curves is attributed to the significantly different drafts of the two ships and the corresponding effects of the submergence of the bow bulb in the light condition. The MERRIMACK was tested at a light displacement draft of 26.9 ft (8.20 m), even keel and the CIMARRON was tested at 21.3 ft (6.50 m) and 2.2 ft (0.67 m) trim by the stern. These curves are considered representative of each ship in the stated test conditions, but, because of the differences in draft and trim, the direct comparison of light load curves is of limited value.

Figures 8 and 9 show the relationship of the primary powering parameters plotted versus shaft speed. These curves are provided for the use of ship's company to allow them to estimate shaft torque and power for performance monitoring purposes based on observed shaft speed and first stage shell pressure.

CONCLUSIONS

1. The maximum speed attained during the Heavy Displacement Standardization Trials was 21.95 kn. A total shaft torque of 1,241,500 lbf-ft (1,682,500 N-m) was achieved at this speed. The maximum shaft power of 23,940 hp (17,860 kW) achieved at this speed was 99% of design power.

2. During the Light Displacement Standardization Trials power levels reached a maximum at 23,610 hp (17,610 kW) which was 98% of design. A corresponding shaft torque and ship speed was 1,230,700 lbf-ft (1,667,800 N-m) and 22.25 kn, respectively.

3. The jumboized MERRIMACK attains a higher maximum speed at full load than the CIMARRON before jumboization.

4. Below 21 knots, the MERRIMACK at full load requires an average of 9% more power than CIMARRON to reach a comparable speed.

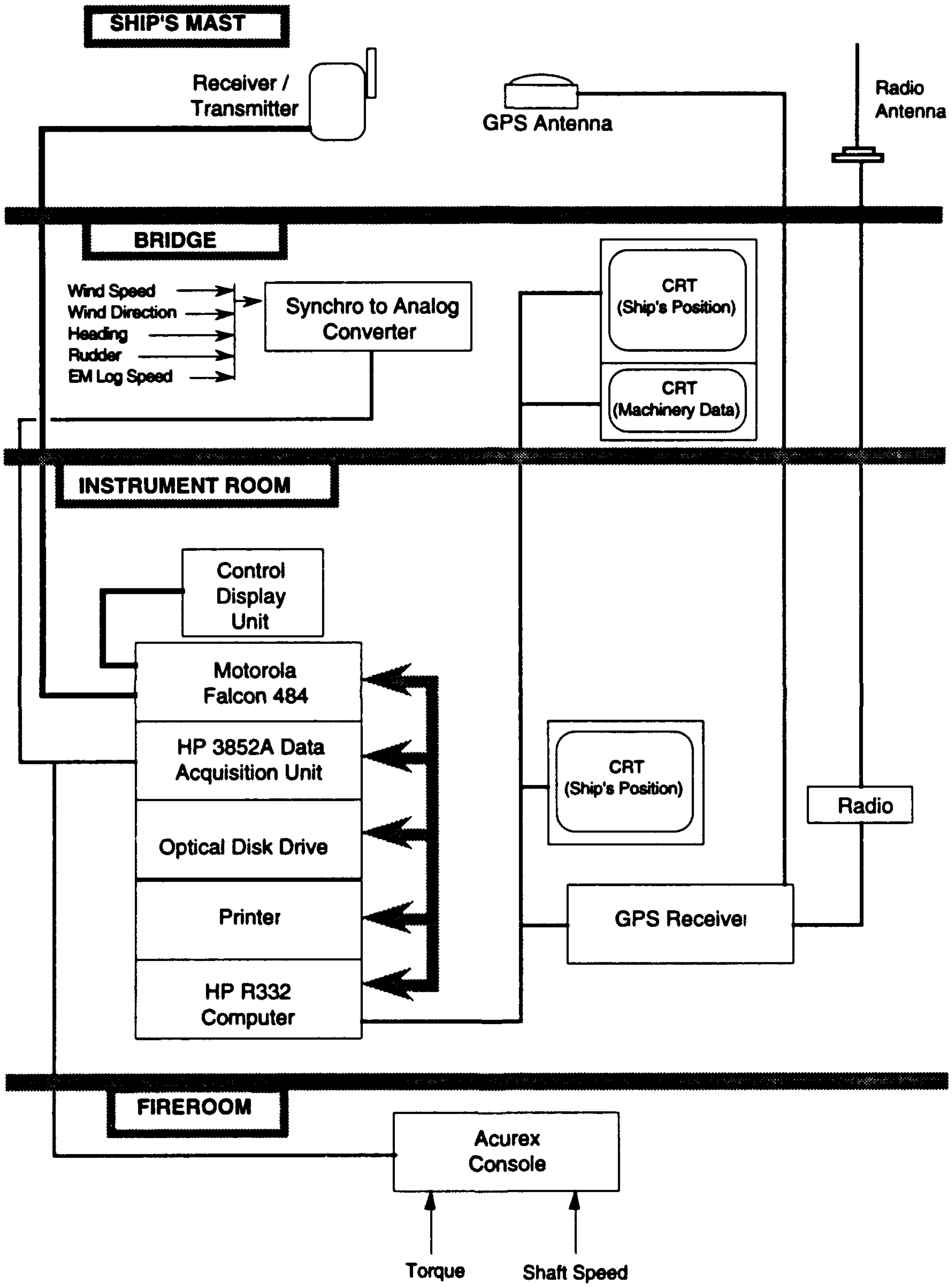

Fig. 1. USS MERRIMACK (AO 179) Jumbo equipment wiring block diagram.

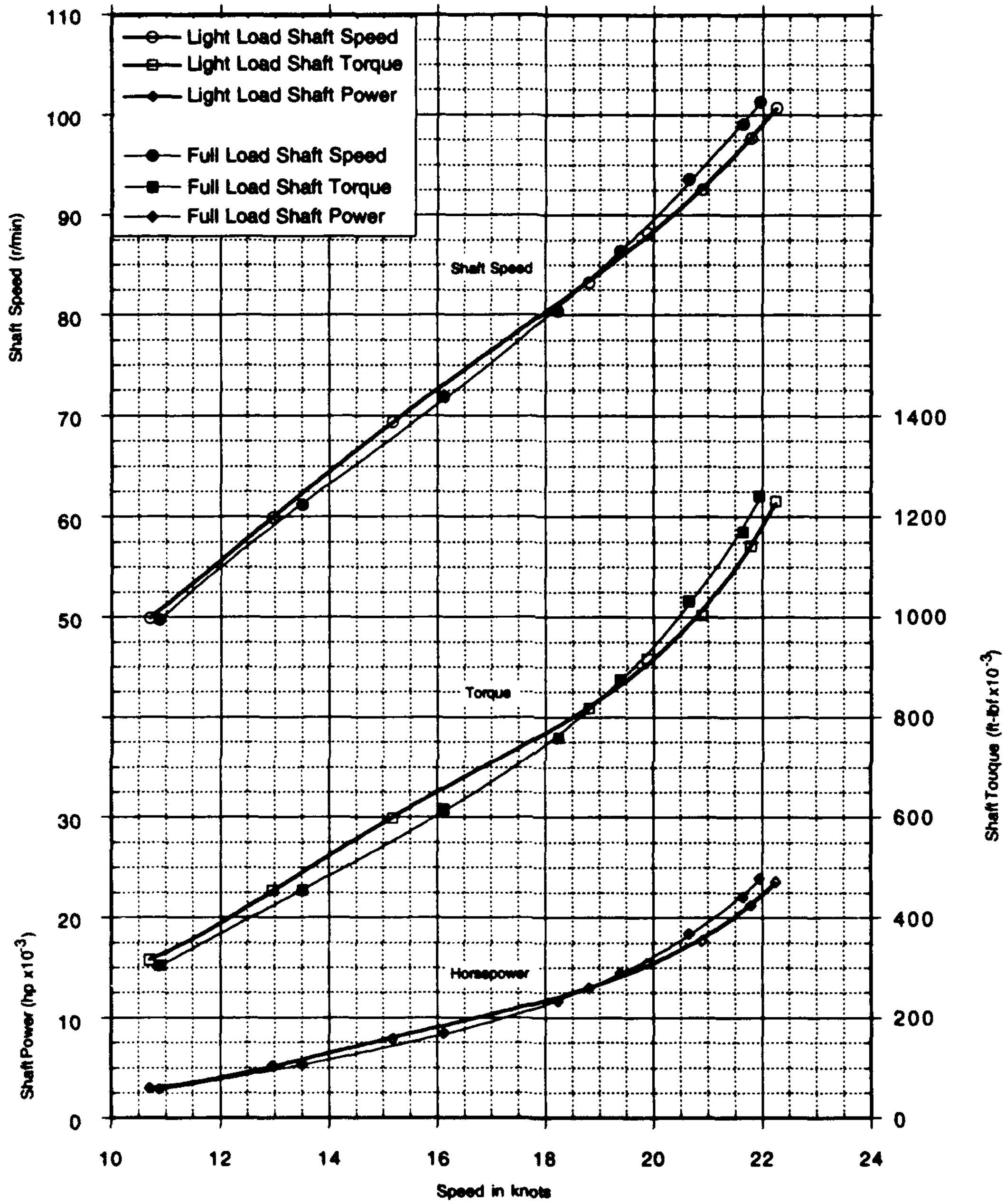

Fig. 2. USS MERRIMACK (AO 179) Jumbo Standardization Trial results for full load and light load displacements (English units).

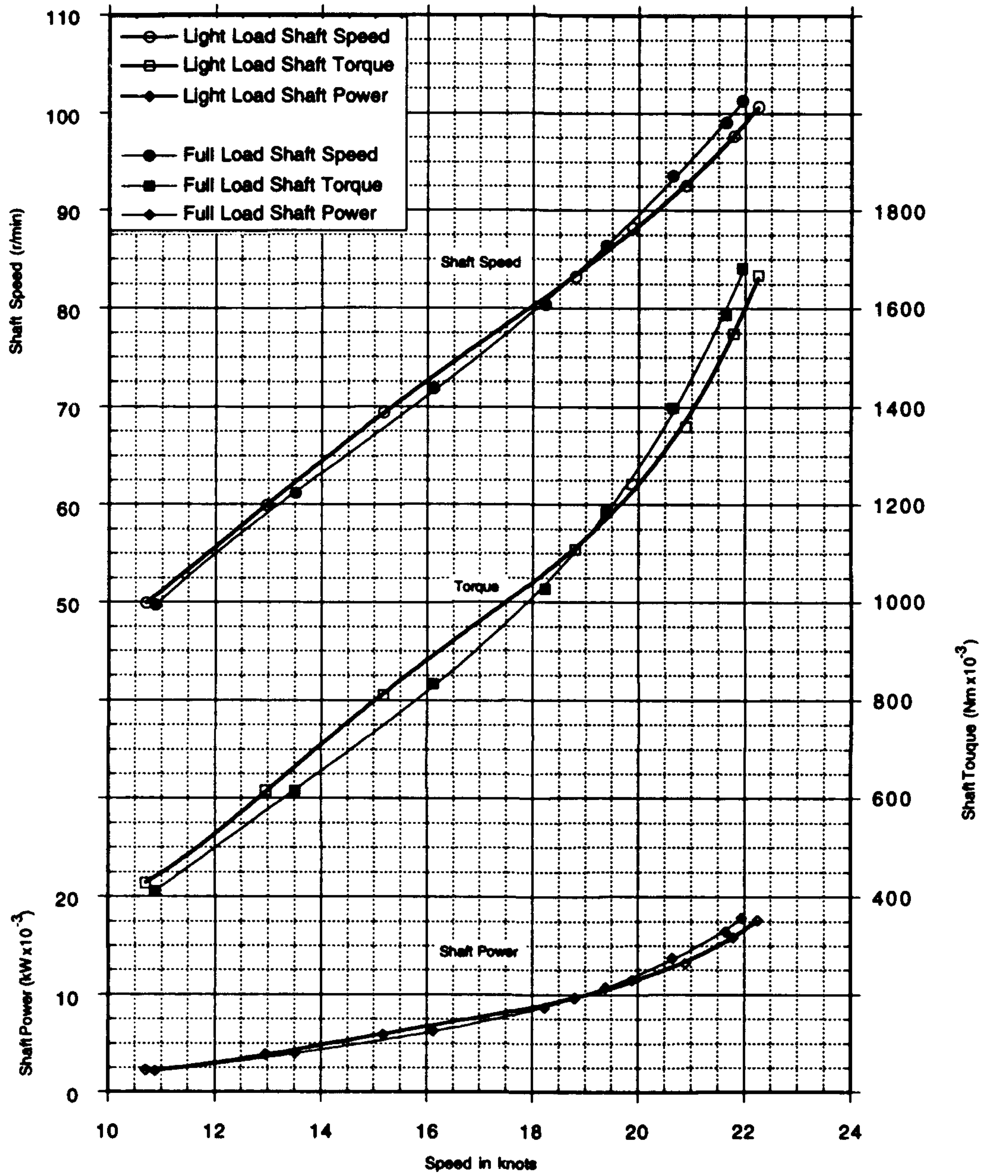

Fig. 3. USS MERRIMACK (AO 179) Jumbo Standardization Trial results for full load and light load displacements (metric units).

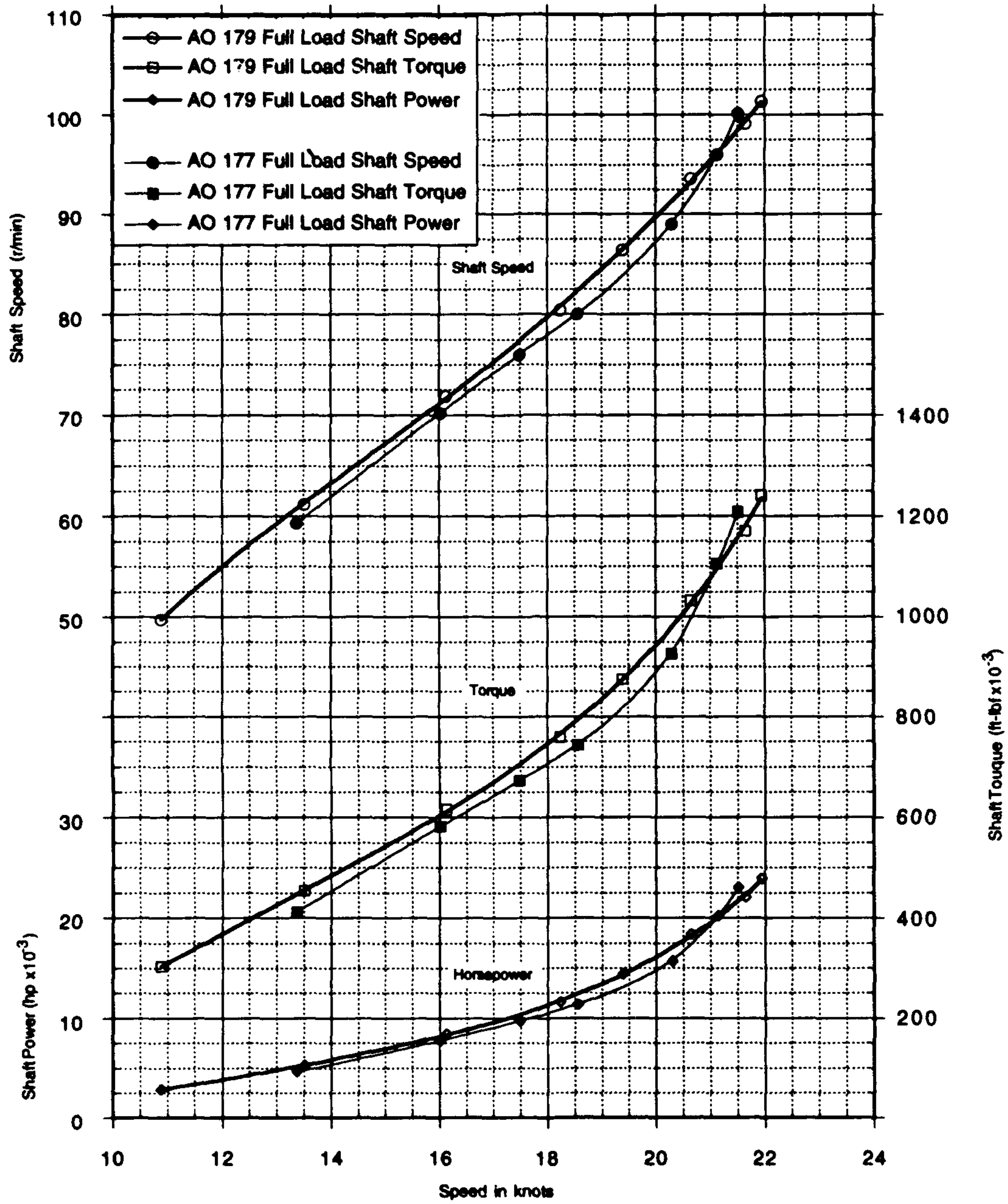

Fig. 4. Comparison of Standardization Trial results of USS MERRIMACK (AO 179) Jumbo and USS CIMARRON (AO 177), both at full load displacement (English units).

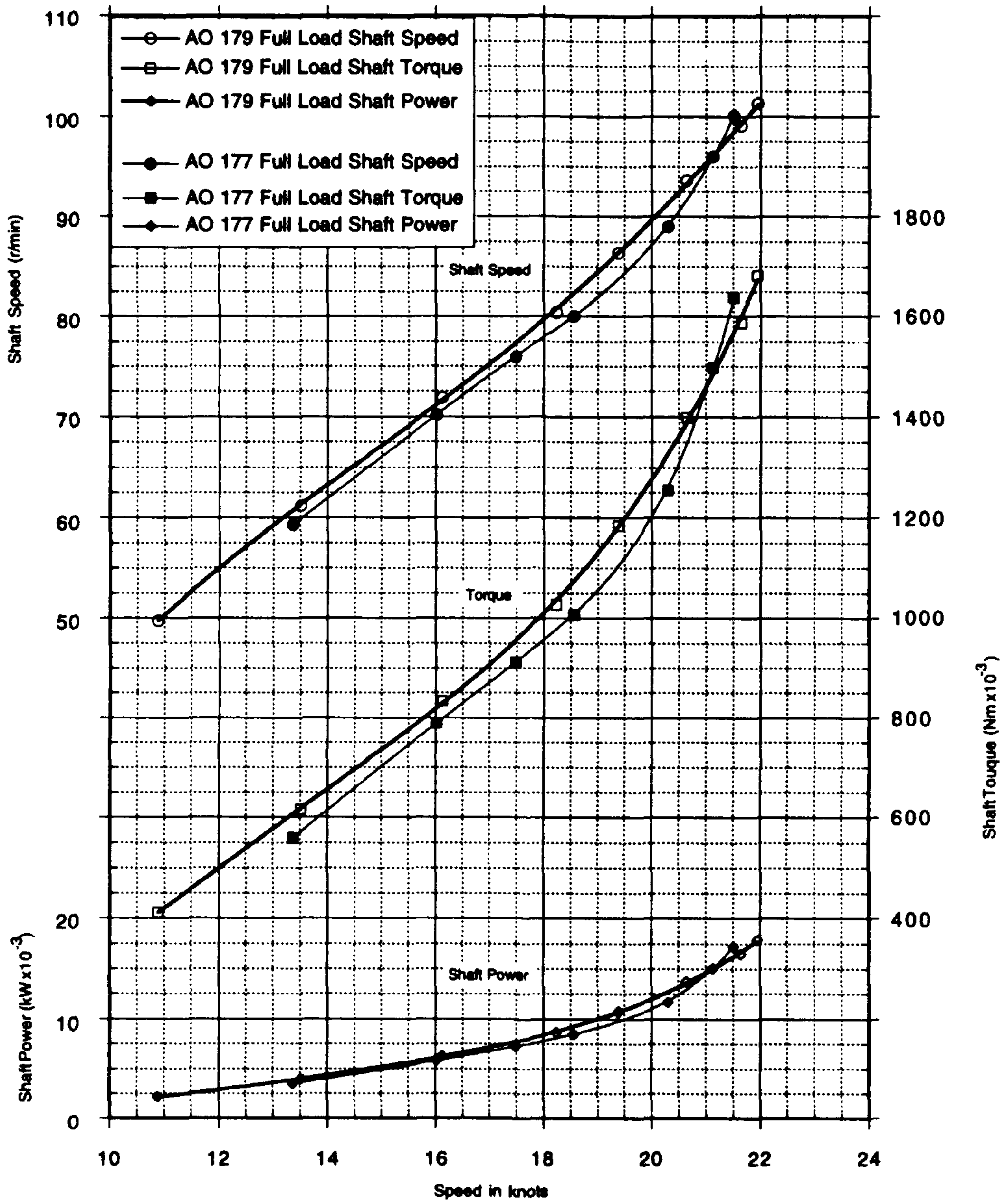

Fig. 5. Comparison of Standardization Trial results of USS MERRIMACK (AO 179) Jumbo and USS CIMARRON (AO 177), both at full load displacement (metric units).

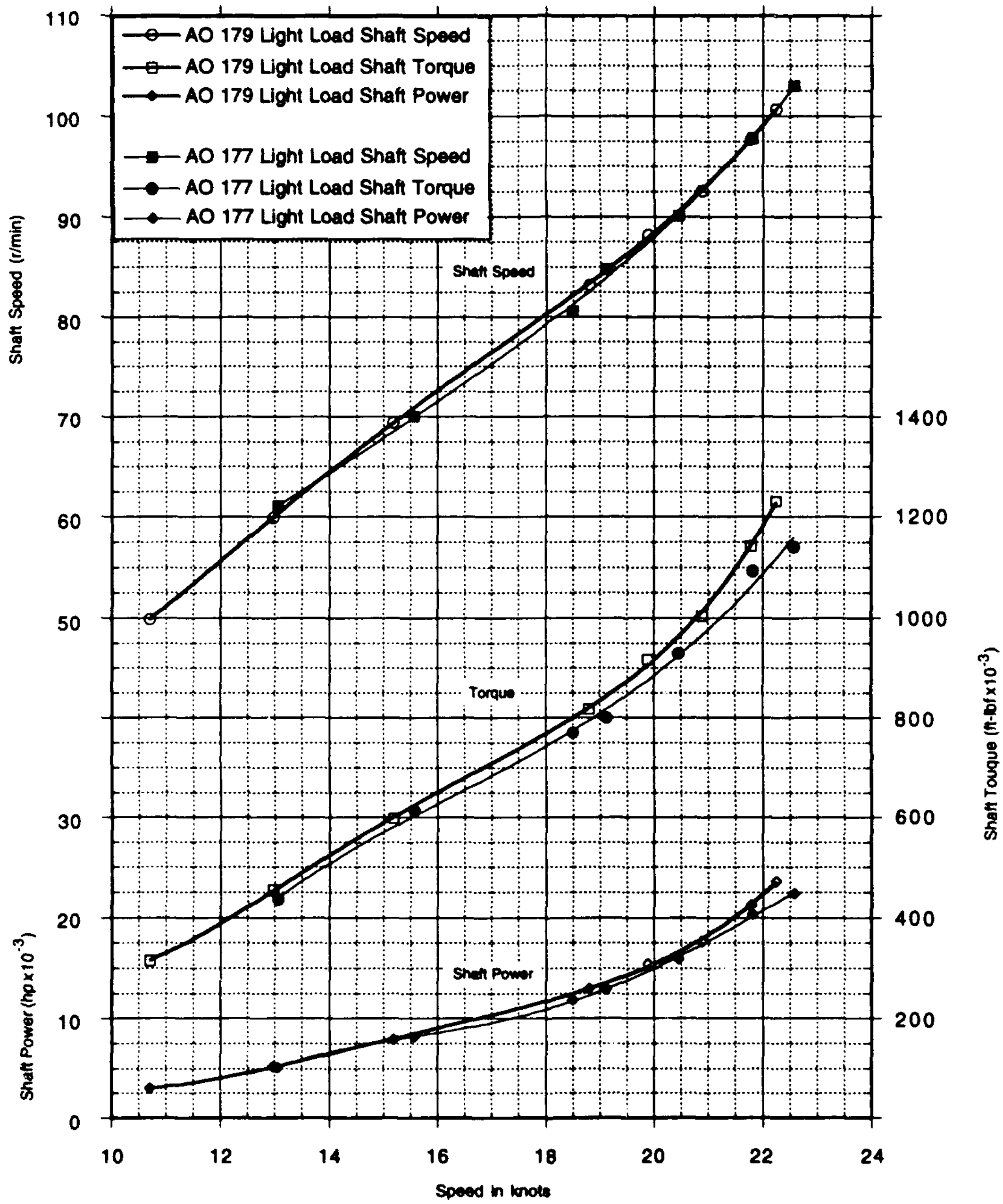

Fig. 6. Comparison of Standardization Trial results of USS MERRIMACK (AO 179) Jumbo and USS CIMARRON (AO 177), both at light load displacement (English units).

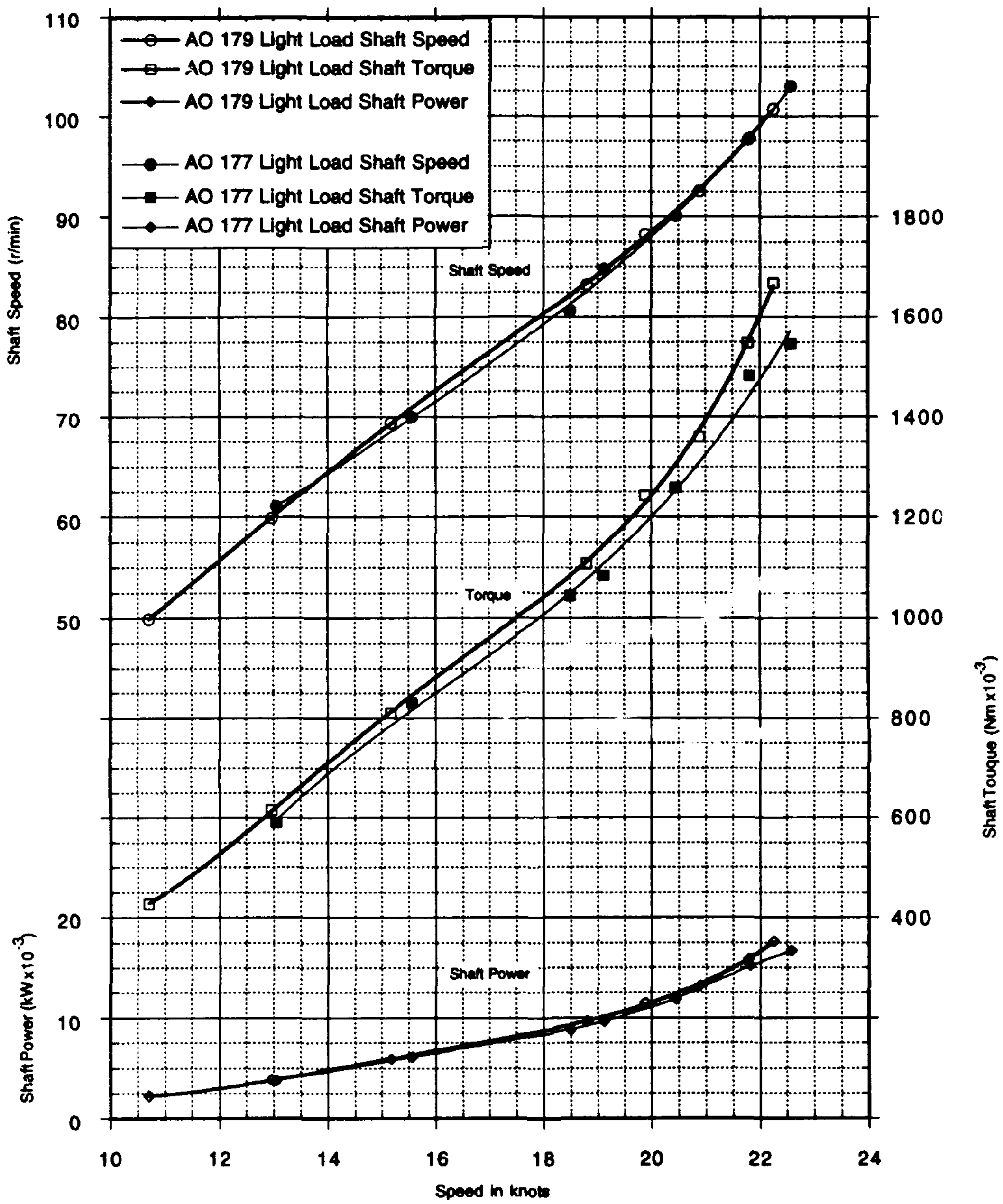

Fig. 7. Comparison of Standardization Trial results of USS MERRIMACK (AO 179) Jumbo and USS CIMARRON (AO 177), both at light load displacement (metric units).

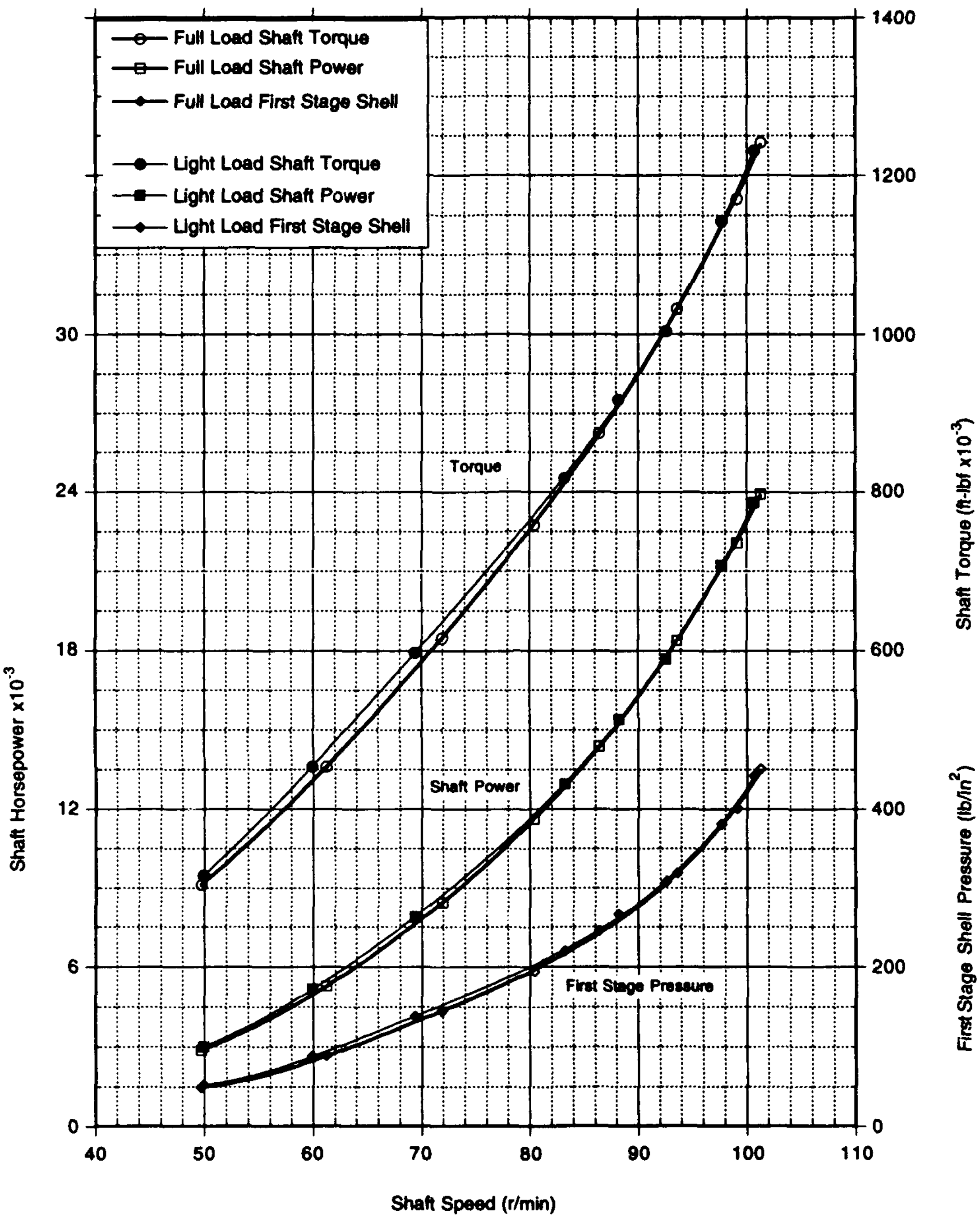

Fig. 8. USS MERRIMACK (AO 179) Jumbo powering data vs. shaft speed (English units).

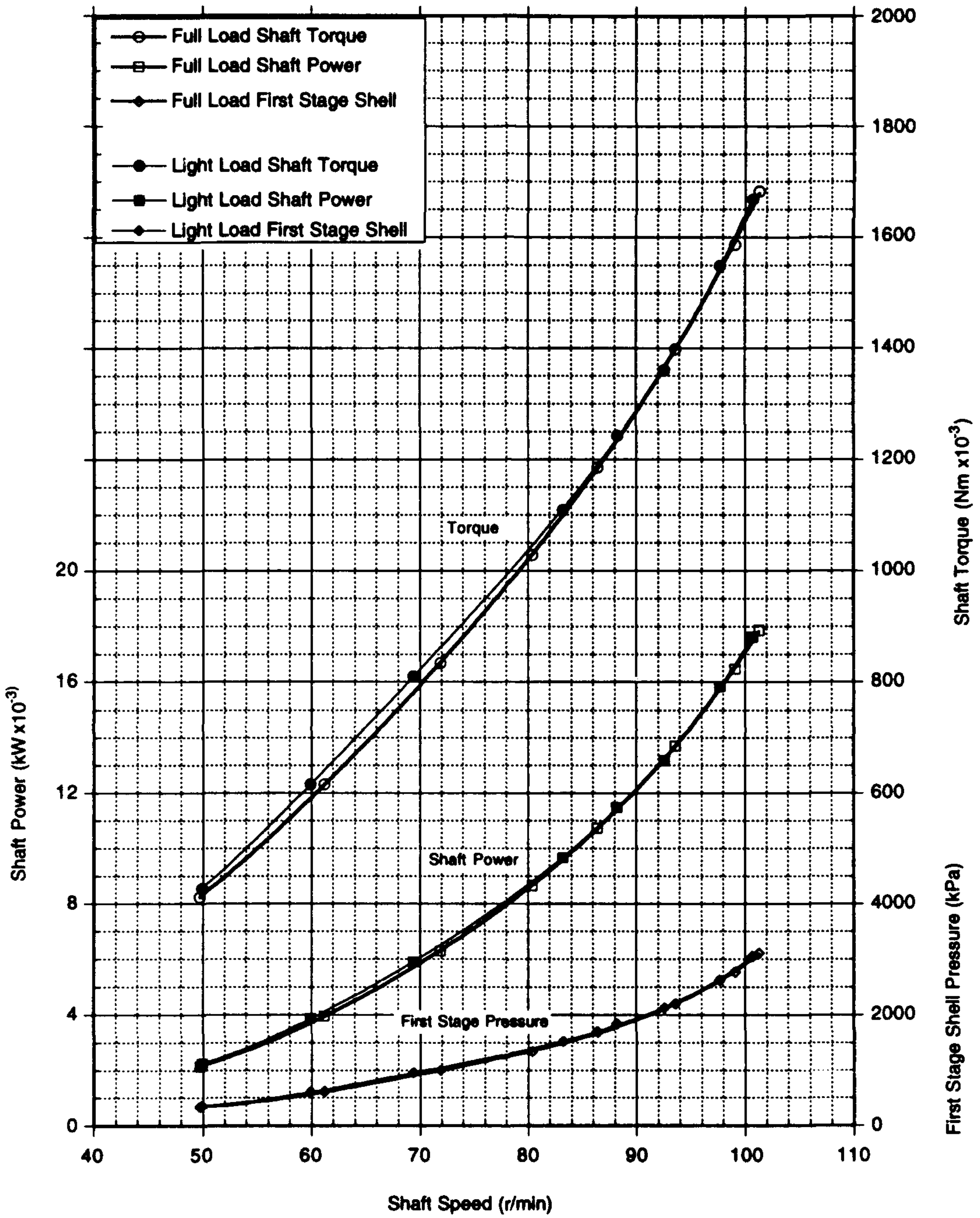

Fig. 9. USS MERRIMACK (AO 179) Jumbo powering data vs. shaft speed (metric units).

Table 1. USS MERRIMACK (AO 179) Jumbo principal ship and propeller characteristics.

SHIP CHARACTERISTICS		
Design displacement, ton (t)	36,890	(37,480)
Length overall (LOA), ft (m)	699.5	(213.2)
Length between perpendiculars (LBP), ft (m)	658.0	(200.5)
Longitudinal center of buoyancy, aft of midships, ft (m)	5.3	(1.6)
Longitudinal center of flotation, aft of midships, ft (m)	20.5	(6.2)
Maximum beam, ft (m)	88.0	(26.8)
Number of rudders	1	
Rudder profile area, ft^2 (m^2)	408.5	(38.0)
Flow accelerating fin wetted surface, ft^2 (m^2)	1104	(102.56)

PROPELLER CHARACTERISTICS		
Number of propellers	1	
Number of blades	5	
Propeller diameter, ft (m)	21.0	(6.40)
Propeller pitch at 0.7 radius, ft (m)	25.79	(7.86)
P/D ratio at 0.7 radius	1.228	
Disc area, ft^2 (m^2)	346.36	(32.18)
Projected area, ft^2 (m^2)	231.72	(21.52)
Expanded area, ft^2 (m^2)	283.43	(26.33)
Propeller weight, lb (kg)	72,400	(32,870)
Fairwater weight, lb (kg)	1,620	(735.5)
Material	Nickel-Aluminum-Bronze	
Manufacturer	Bird-Johnson	
Propeller serial number	29571	
Propeller rotation, ahead direction	Right hand	
Propeller drawing number	245-6609833 Rev. C	

Table 2. USS MERRIMACK (AO 179) Jumbo heavy and light displacement Standardization Trial conditions.

HEAVY DISPLACEMENT STANDARDIZATION TRIALS		
Trial Date	11 July 1991	
Displacement, ton (t)	33,600	(34,100)
Draft forward, ft (m)	30.5	(9.3)
Draft amidships, ft (m)	30.6	(9.3)
Draft aft, ft (m)	30.7	(9.3)
Ship trim by the stern, ft (m)	0.2	(0.1)
Days out of dock	101	
Sea state	1-2	
Water temperature, °F (°C)	82	(27.7)
Water specific gravity	1.023	
True wind direction, deg	286 - 082	
True wind velocity, kn	4 - 10.6	

LIGHT DISPLACEMENT STANDARDIZATION TRIALS		
Trial Date	13-14 July 1991	
Displacement, ton (t)	29,000	(29,500)
Draft forward, ft (m)	26.9	(8.2)
Draft amidships, ft (m)	26.9	(8.2)
Draft aft, ft (m)	26.9	(8.2)
Ship trim, ft (m), by the stern	Even Keel	
Days out of dock	103 - 104	
Sea state	2-3	
Water temperature, °F (°C)	82	(27.7)
Water specific gravity	1.024	
True wind direction, deg	225 - 249	
True wind velocity, kn	11 - 18.5	

Table 3. USS MERRIMACK (AO 179) Jumbo measurement uncertainties.

Measurement	Source	Calibration Source	Resolution*	Bias	Precision
Steady ship speed	Pulse-radar system	Surveyed baseline	0.01 kn	±0.05 kn	±0.10 kn
Shaft Torque	Deflection sensor	Deflection calibration stand	200 lbf-ft (270 N-m)	±2,080 lbf-ft (2,815 N-m)	±16,300 lbf-ft (22,057 N-m)
Shaft speed	Infrared light sensor	Electronic oscillator	0.1 r/min	±0.38 r/min	±1.72 r/min
Wind speed	Anemometer (DC Generator)	Wind tunnel	0.1 kn	±0.1 kn	±1.1 kn
Wind Direction	Anemometer (Synchro transmitter)	Visual alignment	0.1°	±5.0°	±3.3°
Rudder angle	Synchro transmitter	Rudder quadrant	0.1°	±0.25°	±1.20°
Ship heading	Gyrocompass	Gyrocompass	0.1°	±0.25°	±1.40°
Steady EM log speed	Synchro transmitter	Standardization trials	0.05 kn	±0.25 kn†	±0.75 kn
Ship's Draft	Visual/Ship draft computer	Hydrostatic curves of form	0.08 ft (0.025 m)	NA	±0.08 ft (±0.025 m)
Ship's Displacement	Visual/ Ship draft computer	Hydrostatic curves of form	1 in (2.5 cm)	NA	±100 tons (102 t)
First stage shell pressure	Pressure transducer	Pressure calibrator	0.1 psi (0.69 kPa)	±0.5 psig (3.45 kPa)	±0.4 psi (±2.76 kPa)

* Least detectable change in measurement.
† When calibrated.
NA Not Applicable
Note: Uncertainty estimates are based on a general uncertainty analysis of run 1420 from the Standardization Trials, taken as a representative sample.

Table 4. USS MERRIMACK (AO 179) Jumbo torsionmeter characteristics.

Shaft ring serial number	202	
Electronics box number	1-573	
Sensor bar serial number	2-421	
Demodualtor card serial number	2-421	
Filter card serial number	2-509	
Ring bore	18.1540 in	46.111 cm
Design torque	1,260,480 lb-ft	1,708,177 N-m
Distance between shaft ring knife edges	17.655 in	44.843 cm
Modulus of rigidity	11,760,000 lb/in^2	81,082,342 kPa
Shaft outside diameter	18.1540 in	46.111 cm
Shaft inside diameter	Solid shaft	
Y (distance from knife edge to the top of a 1.0 in [2.54 cm] bar)	4.348 in	11.044 cm
Y_c (Y-.5871 in [1.4912 cm]), distance between knife edge and strain gauge)	3.7609 in	9.553 cm
R_s (distance from center of shaft to strain gauge)	12.8379 in	32.608 cm
Full-scale sensor deflection	0.02734 in	0.06944 cm
Torsionmeter gain factor	157.88089 lb-ft/mV	213.95702 N-m/mV

Table 5. USS MERRIMACK (AO 179) Jumbo full load displacement Standardization Trial results at 33,600 long tons displacement, 30.6 ft mean draft, 0.2 ft trim by the stern (English units).

Run Number	EM Log Speed (kn)	Range Speed (kn)	Shaft Speed (r/min)	Shaft Torque (ft-lbf)	Shaft Power (hp)	Relative Wind Speed (kn)	Relative Wind Dir. (deg)	1st Stage Shell Pressure (psi)
1200N	9.7	10.55	49.5	306,600	2,890	15	314	49.2
1210S	10.8	11.20	49.8	296,600	2,810	4	351	47.8
1220N	10.1	10.55	49.7	313,700	2,970	19	1	50.8
Average	**10.3**	**10.88**	**49.7**	**303,400**	**2,870**	-	-	**48.9**
1230S	13.4	13.95	60.7	430,400	4,970	7	352	83.5
1240N	12.9	13.10	61.2	469,800	5,470	21	351	92.2
1250S	13.5	13.90	61.9	446,800	5,260	8	18	88.2
Average	**13.2**	**13.51**	**61.2**	**454,200**	**5,290**	-	-	**89.0**
1260N	15.8	15.90	72.3	636,300	8,750	23	347	150.1
1270S	15.4	16.35	71.5	595,000	8,100	11	4	139.3
Average	**15.6**	**16.13**	**71.9**	**615,600**	**8,430**	-	-	**144.7**
1290N	18.2	18.10	81.1	784,700	12,120	21	351	203.3
1300S	17.5	18.45	80.4	744,900	11,400	14	347	191.1
1310N	17.9	17.90	79.7	758,700	11,510	21	7	193.2
Average	**17.8**	**18.23**	**80.4**	**758,300**	**11,610**	-	-	**194.7**
1320S	18.6	19.55	86.9	872,700	14,430	17	340	245.7
1330N	19.5	19.20	86.0	876,400	14,350	23	11	245.1
Average	**19.0**	**19.38**	**86.4**	**874,500**	**14,390**	-	-	**245.4**
1350N	21.2	20.75	93.7	1,033,300	18,440	24	9	319.8
1360S	19.9	20.55	93.4	1,030,700	18,340	17	344	317.7
Average	**20.6**	**20.65**	**93.6**	**1,032,000**	**18,390**	-	-	**318.8**
1381N	22.3	21.60	98.9	1,172,200	22,080	25	13	401.0
1390S	20.9	21.70	99.2	1,169,100	22,070	18	338	401.0
Average	**21.6**	**21.65**	**99.1**	**1,170,700**	**22,080**	-	-	**401.0**
1410N	22.7	22.00	101.4	1,246,400	24,070	27	9	455.5
1420S	21.2	21.90	101.1	1,236,700	23,810	19	340	446.5
Average	**21.9**	**21.95**	**101.3**	**1,241,500**	**23,940**	-	-	**451.0**

Table 6. USS MERRIMACK (AO 179) Jumbo heavy displacement Standardization Trial results at 34,100 metric tons displacement, 9.32 m mean draft, 0.06 m trim by the stern (metric units).

Run Number	EM Log Speed (kn)	Range Speed (kn)	Shaft Speed (r/min)	Shaft Torque (N-m)	Shaft Power (kW)	Relative Wind Speed (kn)	Relative Wind Dir. (deg)	1st Stage Shell Pressure (kPa)
1200N	9.7	10.55	49.5	415,500	2,160	15	314	339
1210S	10.8	11.20	49.8	401,900	2,100	4	351	329
1220N	10.1	10.55	49.7	425,100	2,220	19	1	350
Average	**10.3**	**10.88**	**49.7**	**411,200**	**2,140**	-	-	**337**
1230S	13.4	13.95	60.7	583,300	3,710	7	352	575
1240N	12.9	13.10	61.2	636,700	4,080	21	351	635
1250S	13.5	13.90	61.9	605,500	3,920	8	18	608
Average	**13.2**	**13.51**	**61.2**	**615,500**	**3,950**	-	-	**613**
1260N	15.8	15.90	72.3	862,300	6,530	23	347	1034
1270S	15.4	16.35	71.5	806,300	6,040	11	4	960
Average	**15.6**	**16.13**	**71.9**	**834,200**	**6,290**	-	-	**997**
1290N	18.2	18.10	81.1	1,063,400	9,040	21	351	1401
1300S	17.5	18.45	80.4	1,009,500	8,500	14	347	1317
1310N	17.9	17.90	79.7	1,028,200	8,590	21	7	1331
Average	**17.8**	**18.23**	**80.4**	**1,027,600**	**8,660**	-	-	**1341**
1320S	18.6	19.55	86.9	1,182,700	10,760	17	340	1693
1330N	19.5	19.20	86.0	1,187,700	10,710	23	11	1689
Average	**19.0**	**19.38**	**86.4**	**1,185,100**	**10,730**	-	-	**1691**
1350N	21.2	20.75	93.7	1,400,300	13,760	24	9	2203
1360S	19.9	20.55	93.4	1,396,800	13,680	17	344	2189
Average	**20.6**	**20.65**	**93.6**	**1,398,500**	**13,720**	-	-	**2196**
1381N	22.3	21.60	98.9	1,588,500	16,470	25	13	2763
1390S	20.9	21.70	99.2	1,584,300	16,460	18	338	2763
Average	**21.6**	**21.65**	**99.1**	**1,586,500**	**16,470**	-	-	**2763**
1410N	22.7	22.00	101.4	1,689,100	17,960	27	9	3138
1420S	21.2	21.90	101.1	1,676,000	17,760	19	340	3076
Average	**21.9**	**21.95**	**101.3**	**1,682,500**	**17,860**	-	-	**3107**

Table 7. USS MERRIMACK (AO 179) Jumbo light displacement Standardization Trial results at 29,000 long tons displacement, 26.9 ft mean draft, even keel (English units).

Run Number	EM Log Speed (kn)	Range Speed (kn)	Shaft Speed (r/min)	Shaft Torque (ft-lbf)	Shaft Power (hp)	Relative Wind Speed (kn)	Relative Wind Dir. (deg)	1st Stage Shell Pressure (psi)
1500N	10.0	11.00	50.0	308,900	2,940	7	258	51.1
1510S	10.4	10.40	49.9	321,800	3,060	23	020	52.9
Average	**10.2**	**10.70**	**49.9**	**315,400**	**3,000**	-	-	**52.0**
1530S	12.2	12.30	58.4	440,100	4,890	21	024	83.2
1540N	12.7	13.60	60.7	455,000	5,260	10	280	89.7
1550S	12.5	12.25	59.9	466,800	5,330	24	026	90.9
Average	**12.5**	**12.96**	**59.9**	**454,200**	**5,180**	-	-	**88.4**
1560S	14.5	14.50	69.1	609,600	8,010	26	024	140.3
1570N	14.8	15.75	69.6	592,800	7,850	13	296	137.4
1580S	15.1	14.70	69.3	596,800	7,880	26	025	138.3
Average	**14.8**	**15.18**	**69.4**	**598,000**	**7,900**	-	-	**138.4**
1590S	18.4	18.05	82.7	819,800	12,910	30	021	219.9
1600N	18.4	19.55	83.7	813,700	12,970	16	298	220.0
1610S	18.4	18.05	82.8	823,800	12,980	31	013	219.9
Average	**18.4**	**18.80**	**83.2**	**817,700**	**12,960**	-	-	**220.0**
1620S	19.7	19.50	87.7	921,000	15,380	35	014	265.7
1630N	19.9	20.60	89.5	931,800	15,870	13	312	275.1
1640S	19.1	18.80	86.0	884,100	14,480	32	015	248.8
Average	**19.7**	**19.88**	**88.2**	**917,200**	**15,400**	-	-	**266.2**
1650N	21.0	21.75	93.3	1,008,300	17,920	16	315	312.4
1660S	20.7	20.15	92.1	1,002,800	17,590	32	015	306.7
1670N	20.7	21.50	92.7	1,001,100	17,670	15	314	306.9
Average	**20.8**	**20.89**	**92.6**	**1,003,800**	**17,690**	-	-	**308.2**
1680N	21.7	22.55	97.8	1,137,900	21,180	17	318	381.5
1690S	21.9	21.05	97.5	1,144,700	21,250	33	022	381.3
1700N	21.8	22.50	97.8	1,142,600	21,290	17	316	381.4
Average	**21.8**	**21.79**	**97.7**	**1,142,500**	**21,240**	-	-	**381.4**
1710S	22.5	21.60	100.7	1,231,900	23,630	33	014	442.4
1720N	22.4	22.90	100.8	1,229,500	23,590	18	328	442.1
1730S	22.5	21.60	100.7	1,231,700	23,620	33	014	442.0
Average	**22.4**	**22.25**	**100.7**	**1,230,700**	**23,610**	-	-	**442.2**

Table 8. USS MERRIMACK (AO 179) Jumbo light displacement Standardization Trial results at 29,500 metric tons displacement, 8.2 m mean draft, even keel (metric units).

Run Number	EM Log Speed (kn)	Range Speed (kn)	Shaft Speed (r/min)	Shaft Torque (N-m)	Shaft Power (kW)	Relative Wind Speed (kn)	Relative Wind Dir. (deg)	1st Stage Shell Pressure (kPa)
1500N	10.0	11.00	50.0	418,600	2,190	7	258	352
1510S	10.4	10.40	49.9	436,100	2,280	23	020	364
Average	**10.2**	**10.70**	**49.9**	**427,400**	**2,240**	-	-	**358**
1530S	12.2	12.30	58.4	596,400	3,650	21	024	573
1540N	12.7	13.65	60.7	616,600	3,920	10	280	618
1550S	12.5	12.25	59.9	632,600	3,980	24	026	626
Average	**12.5**	**12.96**	**59.9**	**615,500**	**3,860**	-	-	**609**
1560S	14.5	14.50	69.1	826,100	5,980	26	024	967
1570N	14.8	15.75	69.6	803,400	5,860	13	296	947
1580S	15.1	14.70	69.[illegible]	808,800	5,880	26	025	953
Average	**14.8**	**15.18**	**[illegible].4**	**810,400**	**5,890**	-	-	**953**
1590S	18.4	18.05	82.7	1,111,000	9,630	30	021	1515
1600N	18.4	19.55	83.7	1,102,700	9,680	16	298	1516
1610S	18.4	18.05	82.8	1,116,400	9,680	31	013	1515
Average	**18.4**	**18.80**	**83.2**	**1,108,100**	**9,670**	-	-	**1515**
1620S	19.7	19.50	87.7	1,248,100	11,470	35	014	1831
1630N	19.9	20.60	89.5	1,262,800	11,840	13	312	1895
1640S	19.1	18.80	86.0	1,198,100	10,800	32	015	1714
Average	**19.7**	**19.88**	**88.2**	**1,243,000**	**11,490**	-	-	**1834**
1650N	21.0	21.75	93.3	1,366,400	13,370	16	315	2152
1660S	20.7	20.15	92.1	1,359,000	13,120	32	015	2113
1670N	20.7	21.50	92.7	1,356,700	13,180	15	314	2115
Average	**20.8**	**20.89**	**92.6**	**1,360,300**	**13,200**	-	-	**2123**
1680N	21.7	22.55	97.8	1,542,100	15,800	17	318	2629
1690S	21.9	21.05	97.5	1,551,300	15,850	33	022	2627
1700N	21.8	22.50	97.8	1,548,400	15,880	17	316	2628
Average	**21.8**	**21.79**	**97.7**	**1,548,300**	**15,850**	-	-	**2628**
1710S	22.5	21.60	100.7	1,669,400	17,630	33	014	3048
1720N	22.4	22.90	100.8	1,666,200	17,600	18	328	3046
1730S	22.5	21.60	100.7	1,669,200	17,620	33	014	3045
Average	**22.4**	**22.25**	**100.7**	**1,667,800**	**17,610**	-	-	**3046**

Table 9. USS MERRIMACK (AO 179) Jumbo powering table showing standard speed increments at the normal operating condition (full load).

Ship Speed (kn)	Shaft Speed (r/min)	Shaft Torque (ft-lbf)	Shaft Torque (N-m)	Shaft Power (hp)	Shaft Power (kW)
10	45.7	254,500	344,900	2,150	1,600
11	50.2	310,100	420,200	2,970	2,220
12	54.7	366,500	496,700	3,840	2,860
13	59.0	424,300	575,000	4,780	3,570
14	63.2	483,600	655,400	5,830	4,350
15	67.3	544,400	737,800	6,990	5,210
16	71.4	607,400	823,100	8,260	6,160
17	75.4	672,600	911,500	9,650	7,200
18	79.5	742,900	1,006,800	11,250	8,390
19	84.4	835,000	1,131,600	13,440	10,030
20	89.9	949,600	1,286,900	16,280	12,140
21	95.5	1,080,100	1,463,700	19,660	14,670
22	101.7	1,254,300	1,699,800	24,280	18,110
23	109.3	1,511,300	2,048,100	31,000	23,130

APPENDIX A

DESCRIPTION OF THE HATTERAS EAST COAST TRACKING OFFSHORE RANGE (HECTOR)

The Hatteras East Coast Tracking Offshore Range (HECTOR) is located 50 nmi (92.6 km) northeast of Cape Hatteras, North Carolina and 87 nmi (161 km) southeast of Norfolk, Virginia. The range site makes use of two of four offshore towers which are used for Navy pilot training. The North tower, the most easterly of the four towers, is located at lat. 36°03'52"N and long. 74°59'00"W . The South tower is located at lat. 35°47'11"N and long. 75°05'42"W. These unmanned towers are 75 ft (22.9 m) high and 17.54 nmi (32.5 km) apart and are utilized as platforms for permanently mounted tracking instrumentation.

The primary means of determining ship position is the Motorola Mini-Ranger Falcon 484 pulse tracking system. A transmitter located on the ship was used to interrogate reference station transponders mounted on the towers. The elapsed time between the transmitted interrogation produced by the Falcon transmitter and the reply received from each transponder was used as the basis for determining the distance to each transponder. This range information, together with the known location of each transponder, was triangulated to provide a positional fix on the ship. Successive positional fixes enable the calculation of ship speed as well as its turning and maneuvering capabilities.

Since tracking accuracy is related to system geometry, ship trials are normally conducted within a 4.0 nmi^2 (13.7 km^2) area as shown in Fig. A.1. The center of this area (lat. 35°52'30"N and long. 74°51'00"W) is approximately 9.6 nmi (17.8 km) from the midpoint of the distance between the towers in a direction perpendicular to the baseline determined by the two towers. The approach for each trial run is generally conducted near the center of the tracking area on a course parallel with the baseline determined by the towers. Thus, a heading of 018° T is used for north runs and a heading of 198° T is used for south runs. Water depth is in excess of 300 ft (91.4 m).

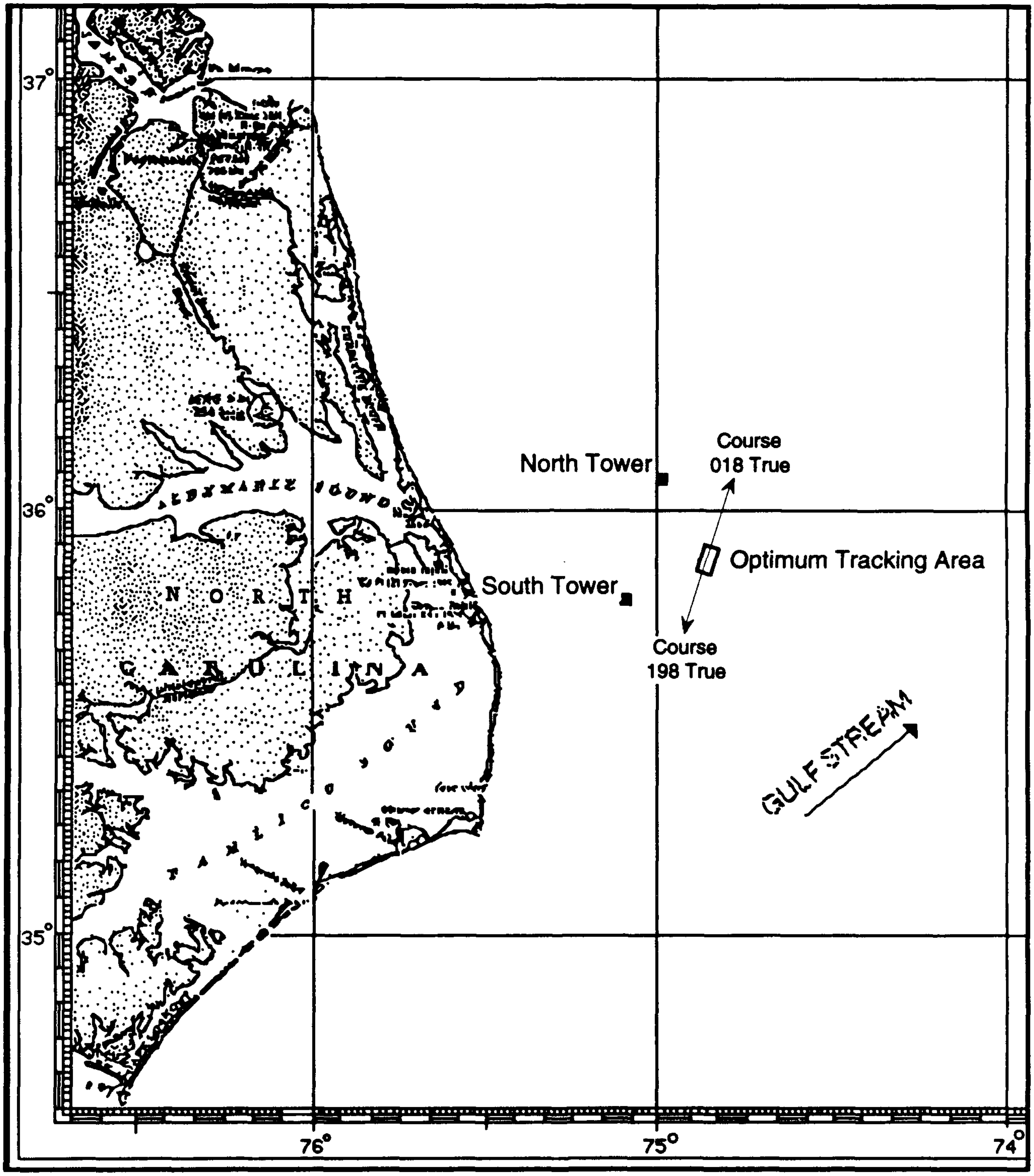

Fig. A.1. HECTOR tracking range area chart.

APPENDIX B

USS MERRIMACK (AO 179) JUMBO HULL ROUGHNESS MEASUREMENTS

Roughness measurements of MERRIMACK's hull, bow area, rudder, fin and propeller were taken by Carderock Division, Naval Surface Warfare Center (CARDEROCKDIV, NSWC) divers. Based on the diver video and photographic survey of the ship, the MERRIMACK's hull and appendages satisfied the NAVSEA Technical Manual S9086-CQ-STM-000 Chapter 081[2] conditions for conducting Navy Standardization Trials. The results of the roughness survey are summarized in Table B.1.

A British Ship Research Association (BSRA) Mark II Roughness Analyzer was used to collect peak-to-peak roughness measurements at representative locations throughout the underwater hull area as well as on the ship's appendages. This device measures the roughness in terms of the mean apparent amplitude, i.e., it measures the average peak-to-peak distance in micrometers (μm) for fifteen 50 mm (2 in.) sample lengths. These 15 sample lengths are taken over a total of 750 mm (29.5 in.) length of surface. This length is known as one data length. For each data length the individual values of the 15 sample lengths are printed and the average roughness value for that particular area is printed. This average is the recorded roughness reading for that particular data length.

The BSRA trolley was moved across the surface in the direction of the water flow to yield the best results. The unit was operated in this manner throughout the hull survey unless otherwise noted.

Table B.2. compares the roughness survey from the MERRIMACK to some of the other ships for which similar data are available. Generally, the MERRIMACK's hull was smoother than the average of other ships tested.

Table B.1. USS MERRIMACK (AO 179) Jumbo hull roughness survey.

General Area	Number of readings taken	Maximum		Minimum		Average	
		(μm)	(in)	(μm)	(in)	(μm)	(in)
Aft keel	2	302	0.0119	296	0.0117	299	0.0118
Aft port quarter at 27 ft draft mark	2	188	0.0074	160	0.0063	174	0.0069
Aft port quarter at 23 ft draft mark	3	178	0.0070	172	0.0068	175	0.0069
Aft starboard quarter at 27 ft draft mark	3	138	0.0054	110	0.0043	122	0.0048
Aft starboard quarter at 21 ft draft mark	2	154	0.0061	152	0.0060	153	0.0060
Frame 60, port side at 27 ft draft mark	3	212	0.0084	200	0.0079	206	0.0081
Frame 60, port side at 21 ft draft mark	2	204	0.0080	202	0.0080	203	0.0080
Frame 60, at keel	2	228	0.0090	220	0.0087	224	0.0088
Frame 30, starboard side at 27 ft draft mark	5	222	0.0087	172	0.0068	184	0.0072
Frame 30, starboard side at 21 ft draft mark	3	168	0.0066	154	0.0061	159	0.0063
Frame 30, at keel	3	186	0.0073	162	0.0064	171	0.0067
Frame 45, port side at 27 ft draft mark	4	204	0.0080	156	0.0061	184	0.0072
Frame 45, port side at 21 ft draft mark	3	268	0.0106	244	0.0096	255	0.0100
Frame 45, at keel	5	260	0.0102	184	0.0072	217	0.0085
Total hull roughness	**42**	**208**	**0.0082**	**185**	**0.0073**	**195**	**0.0077**
Starboard side of fin, bottom	4	184	0.0072	158	0.0062	172	0.0068
Starboard side of fin, top	5	416	0.0164	230	0.0091	308	0.0121
Total fin roughness	9	300	0.0118	194	0.0076	240	0.0095
Starboard side of rudder	4	154	0.0061	112	0.0044	132	0.0052
Port side of rudder	3	168	0.0066	154	0.0061	163	0.0064
Total rudder roughness	**7**	**161**	**0.0063**	**133**	**0.0052**	**148**	**0.0058**
Bow area, at keel	4	240	0.0095	138	0.0054	175	0.0069
Starboard side bow area, at 27 ft draft mark	4	366	0.0144	324	0.0128	341	0.0134
Starboard side bow area, at 21 ft draft mark	2	280	0.0110	250	0.0098	265	0.0104
Port side bow area, at 27 ft draft mark	5	228	0.0090	144	0.0057	174	0.0069
Port side bow area, at 21 ft draft mark	4	254	0.0100	180	0.0071	206	0.0081
Total bow area roughness	**19**	**273.6**	**0.0108**	**207**	**0.0082**	**232**	**0.0091**
Propeller blade 1, pressure side	2	142	0.0056	122	0.0048	132	0.0052
Propeller blade 1, suction side	2	90	0.0035	68	0.0027	79	0.0031
Propeller blade 2, pressure side	2	156	0.0061	140	0.0055	148	0.0058
Propeller blade 2, suction side	2	172	0.0068	154	0.0061	163	0.0064
Propeller blade 3, pressure side	2	146	0.0058	132	0.0052	139	0.0055
Propeller blade 3, suction side	2	126	0.0050	98	0.0039	112	0.0044
Propeller blade 4, pressure side	2	150	0.0059	142	0.0056	146	0.0058
Propeller blade 4, suction side	2	76	0.0030	68	0.0027	72	0.0028
Propeller blade 5, pressure side	2	122	0.0048	106	0.0042	114	0.0045
Propeller blade 5, suction side	2	72	0.0028	68	0.0027	70	0.0028
Total propeller roughness	**20**	**125.2**	**0.0049**	**110**	**0.0043**	**118**	**0.0046**

Table B.2. USS MERRIMACK (AO 179) Jumbo hull roughness comparison.

Ship	Area	Number of Readings Taken	Average Roughness (μm)	(in)
CVN 71	HULL	62	264	0.0104
CV 41	HULL	85	233	0.0092
CV 41	HULL	35	210	0.0083
LSD 41	HULL	25	192	0.0076
CG 49	HULL	68	140	0.0055
AO 179	**HULL**	**61**	**205**	**0.0081**
CVN 71	RUDDER(s)	15	291	0.0115
CV 41	RUDDER(s)	14	194	0.0076
CV 41	RUDDER(s)	10	183	0.0072
LSD 41	RUDDER(s)	4	257	0.0101
CG 49	RUDDER(s)	4	250	0.0098
AO 179	**RUDDER(s)**	**7**	**148**	**0.0058**
CVN 71	STRUTS	5	344	0.0136
CV 41	STRUTS	12	380	0.0150
CV 41	STRUTS	15	408	0.0161
LSD 41	STRUTS	6	293	0.0115
CG 49	STRUTS	7	169	0.0067
AO 179	**FIN**	**9**	**240**	**0.0095**
CVN 71	PROPELLER(s)	31	112	0.0044
CV 41	PROPELLER(s)	30	118	0.0046
CV 41	PROPELLER(s)	20	229	0.0090
LSD 41	PROPELLER(s)	8	72	0.0028
CG 49	PROPELLER(s)	N/A	N/A	N/A
AO 179	**PROPELLER(s)**	**20**	**118**	**0.0046**

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APPENDIX C

USS MERRIMACK (AO 179) JUMBO DISPLACEMENT CALCULATIONS

The following discussion explains the process for determining the displacement of MERRIMACK during these trials. Displacement and trim values were developed from the internal draft mark indicator readings observed in Damage Control Central (DCC) and the ship's displacement/draft curves. Figure C.1 is a time history of draft readings taken during the Standardization Trials. Average values of draft were obtained over the length of each individual trial (see Fig. C.1) and are tabulated in Table C.1, along with the corresponding calculated displacement.

External draft readings were taken in Norfolk, while the ship was tied to the pier on 3 and 7 July 1989. Comparison between the internal and external draft readings show good agreement. External draft readings were not available during the Standardization Trials period. In light of the favorable agreement between internal and external draft mark readings, it was concluded that the DCC internal draft mark readings were representative of MERRIMACK's displacement and trim.

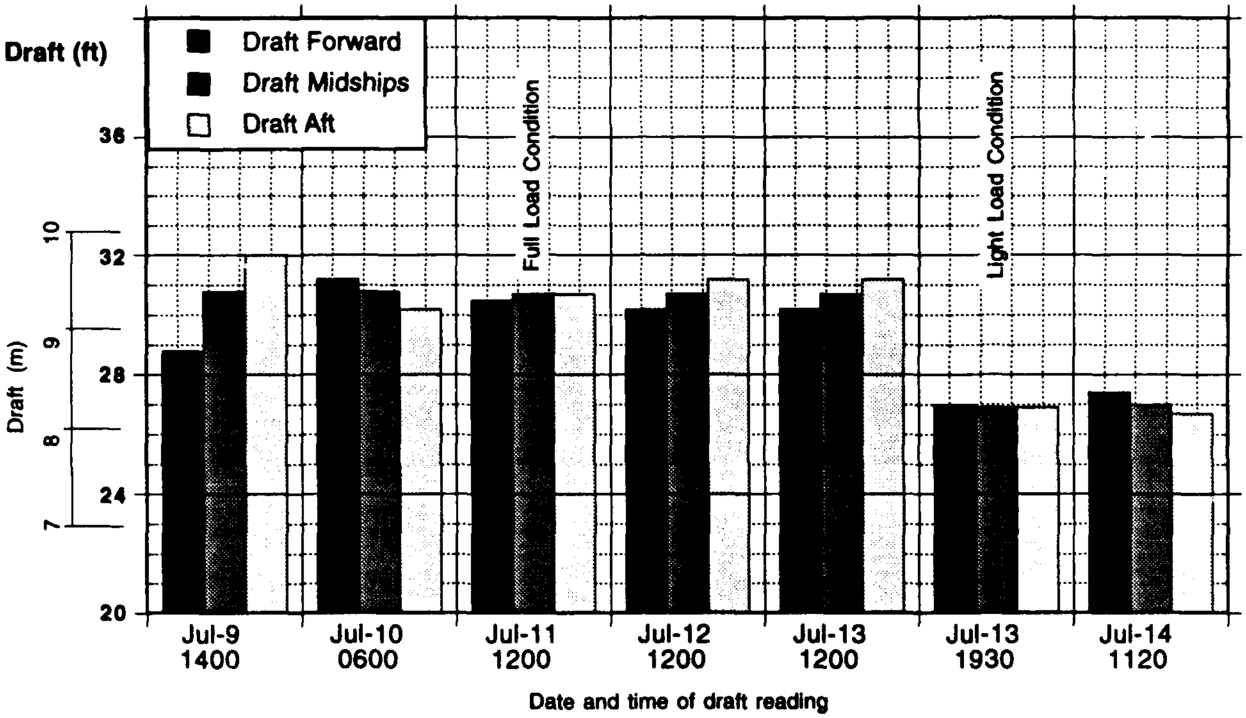

Fig. C.1. Time history of draft readings taken during Performance and Special Trials on USS MERRIMACK (AO 179) Jumbo.

Table C.1. Draft readings taken during Standardization Trials on USS MERRIMACK (AO 179) Jumbo.

Date	Time	Draft Forward ft (m)	Draft Midships ft (m)	Draft Aft ft (m)	Displacement long tons (metric tons)
9-Jul-91	1400	28.8 (8.7)	30.8 (9.4)	32.0 (9.8)	33,600 (34,200)
10-Jul-91	0600	31.2 (9.5)	30.8 (9.4)	30.2 (9.2)	33,800 (34,300)
11-Jul-91	1200	30.5 (9.3)	30.7 (9.3)	30.7 (9.3)	33,600 (34,100)
12-Jul-91	1200	30.2 (9.2)	30.7 (9.3)	31.2 (9.5)	33,700 (34,200)
13-Jul-91	1200	30.2 (9.2)	30.7 (9.3)	31.2 (9.5)	33,700 (34,200)
13-Jul-91	1930	26.9 (8.2)	26.9 (8.2)	26.9 (8.2)	29,000 (29,500)
14-Jul-91	1120	27.4 (8.4)	27.0 (8.2)	26.7 (8.1)	29,100 (29,600)

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